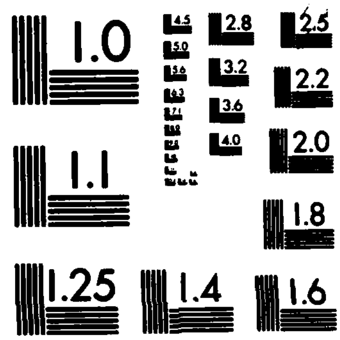

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ULTRAVIOLET AND X-RAY SPECTROSCOPY OF ASTROPHYSICAL AND LABORATORY PLASMAS

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NRL, WASHINGTON, DC

16 MAY 1983

UNITED STATES OF AMERICA

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The meeting concentrated on four categories of studies: solar; laboratory; stellar, interstellar, and galactic; and theoretical.

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ULTRAVIOLET AND X-RAY SPECTROSCOPY OF ASTROPHYSICAL AND LABORATORY PLASMAS

An International Astronomical Union Meeting, Ultraviolet and X-ray Spectroscopy of Astrophysical and Laboratory Plasmas, was held on the Belfield Campus of the Univ. of Dublin, Ireland, from 30 August through 1 September 1982. Over 80 scientists from 13 countries in the astronomical, plasma, and atomic physics communities participated in an exchange of both theoretical and experimental research.

It is significant that such an exchange took place at this time because short-wavelength astrophysical satellite-borne experiments are producing data that can be directly compared with results from high-temperature plasma spectroscopy in the laboratory. The comparison provides a broad data base to check the validity of theoretical models, particularly in the case of highly ionized atoms.

The presentations on the program were divided into four categories of studies: solar; laboratory; stellar, interstellar, and galactic; and theoretical. In each category, there were at least two invited talks, which focused on recent major developments. Contributed talks followed, and poster papers from all categories were left on display in rooms adjoining the main lecture room for two of the three meeting days. A program and abstract booklet has been printed by the Physics Department, University College Dublin, Belfield, Dublin 4, Ireland.

Solar Studies

Invited Talks

Dr. J.L. Culhane (University College, London) and Dr. George Doschek (Naval Research Laboratory, Washington, DC) covered the analysis of solar flare x-ray spectra in the 1.8- to 25-angstrom range obtained with spectrometers aboard the Solar Maximum Mission and the P78-1 US Air Force satellites. Spectra from He-like and Li-like lines of O, Ne, Mg, S, Ca, Cr, and Fe, and their time histories in solar flares were shown. Besides the usual temperature and density diagnostics, emission mechanisms such as production of Kα radiation by fluorescence and mass motion effects in x-type flares were discussed.

Contributed Talks

L. Acton (Lockheed Palo Alto Research Laboratory, Palo Alto, CA) gave results of an analysis of the dynamical processes of energy deposition and transfer during the thermal phase of a flare observed on the Solar Maximum Mission. The x-ray observations suggest that a rapid heating and hydrodynamic flare model fit the data.

M. Bruner, also from the Lockheed laboratory, presented spectroheliograms and Dopplergrams of bright loops observed on the Solar Maximum Mission in C IV (λ = 1548 angstrom) light. Both steady and nonsteady state mass flow models which fit the velocity and intensity data have been formulated.

J.R. Lemen (Mullard Space Science Laboratory, Dorking, Surrey, UK) showed K spectra of Fe ions obtained with the P78-11 satellite. The lines have been observed both in Tokamaks and solar flares, and calculations of the density dependence agree with both types of data. The relative abundance of Fe XXV obtained from the x-ray resonance line has shown that there is no coronal ionization equilibrium in solar flares, a fact not yet explained by flare models. It was also shown that dielectronic recombination lines from n greater than 2 must be taken into account when analyzing laboratory and solar K spectra of Fe.

J. Schrijver (Space Research Laboratory, Utrecht, the Netherlands) described a method using selected x-ray line ratios as a density diagnostic in solar plasmas that are in a state of transient ionization. Comparison with Ca and Fe x-ray data appears to show no measurable transient conditions on time scales of 10 to 60 seconds.

L. Steenman-Clark (Observatoire de Nice, France) emphasized that when one interprets line ratios, unresolved satellite contributions to the He-like resonance line must be accounted for. Ti XXI spectra from the Princeton PDX Tokamak were shown.

Posters

D.L. McKenzie (Aerospace Corp., Los Angeles, CA) presented solar K line spectra of Ne and O from different regions on the sun. Electron densities were determined by using the ratios of resonance, intercombination, and forbidden lines of He-like ions. Corrections for resonance scattering in the solar corona were made by looking for variations in the line ratios in time and space.

R. Catura (Lockheed Palo Alto Research Laboratory Palo Alto, CA) showed a spectrum of a solar flare taken with a grating spectrograph aboard a rocket flight. Lines from N, O, Ne, Mg, Si, and Fe ions in the 12- and 95-angstrom range were identified.

Laboratory Studies

Invited Talks

Talks by E. Kallne (Center for Astrophysics, Cambridge, MA) and S. Suckewer (Princeton Plasma Physics Laboratory) focused on the use of Tokamak plasmas as sources of radiation for atomic physics and plasma data analysis. It was shown how natural and injected impurities in the plasma could be used to obtain spectroscopic information for determining plasma transport, temperatures and densities, and atomic rates. It was stressed that even though steady state models apply to the plasmas, particle transport must be taken into account when interpreting the data. K-shell spectra of S, Cl, Sc, Ti, Fe, and Ni were shown.

In contrast, M. Klapisch (Hebrew Univ., Israel) presented new results on the analysis of isoelectronic sequences having L and M shell electrons. Recent theoretical calculations were used to predict the mean wavelengths and widths of transition arrays of lines blended together in spectra of rare earth ions.

J.D. Kilkenny (Imperial College, London) presented spectra from laser-produced plasmas that were used to obtain temperature and density from Li-like satellites. Radiation transport and opacity effects complicate the interpretation. Absorption spectroscopy of the K photoionization edge in preheated solids yielded plasma electron densities.

Contributed Talks

B. Tartar (Lawrence Livermore National Laboratory, Livermore, CA) gave a progress report on the gas-puff Z-pinch facility (ZAPP) at Livermore. The device is being used to create plasmas from noble gases such as argon and krypton, with emphasis on determining rate coefficients and producing stimulated x-ray emission. A variety of spectral measurements from the far infrared to the hard x-ray region are being made.

M. Finkenthal (Hebrew Univ., Jerusalem, Israel) presented spectra of Ne-like ions at wavelengths greater than 100 angstroms obtained on the TFR Tokamak in France. Interpretation of the data show that the ions are indicators of local changes in density and temperature in TFR.

W. Ott (National Bureau of Standards, Washington, DC) discussed a vacuum ultraviolet (VUV) plasma source that has the following advantages: a small radiation surface area (0.3 × 10 mm), reproducible operation, uniform radiance, and low power operation. The source is produced by a corona discharge in a noble gas.

W. Parkinson (Harvard College Observatory, Cambridge, MA) measured the lifetime of the $3s3p\,^3P_1-3s^2\,^1S_0$ transition in Si III ions in order to determine the transition probability. Other measurements in progress include lifetimes of transi-

tions in Si II, C II, C III, and O III ions.

W. Hill (National Bureau of Standards) showed the absorption spectrum of Ba III produced using a laser plasma. The autoionization lines are less intense than expected from xenon lines in the same sequence. The behavior is explained by reduced channel mixing according to multichannel quantum defect theory.

P.K. Carroll (University College, Dublin, Ireland) presented laser-produced spectra of Xe VII, VIII, IX, and X at wavelengths less than 200 angstroms. Carroll observed a complex structure similar to features in Cs, Ba, La, and Ce spectra.

In laser-produced spectra, S.S. Churilov (USSR Academy of Sciences, Moscow) showed line broadening caused by source size. Doublets caused by Doppler shifts in hollow cone-shaped plasma were also observed in Fe XVIII-Fe XXI lines.

J.G. Lunney (Trinity College, Dublin) presented Ar and Si K-shell spectra from laser imploded microballoons and used the data to derive temperature and density in the plasma.

G. O'Sullivan (National Institute for Higher Education, Dublin) discussed laser-produced VUV spectra of elements with atomic numbers 62-74. The spectra lacked strong lines because of the complexity of the electron configurations in the elements and level crossing of the 4f-5p and 4f-5s subshells. It was demonstrated that a high radiance source (greater than 10^{23} photons cm^{-1} $-sr^{-1}$-A^{-1}-sec^{-1}) of VUV continua is available from plasmas made from the elements.

M.L. Ginter (Univ. of Maryland, College Park, MD) described a 10-Hz, repetitively pulsed, Nd laser used to produce plasmas that emitted x-rays useful for emission and absorption spectroscopy and x-ray lithography.

E. Jannitti (Univ. di Padova, Italy) showed absorption spectra in the 40- to 300-angstrom range of light ions such as Be II, Be III, and C IV. The results were obtained by backlighting the laser-produced plasma with a high Z plasma produced by the same laser using a beam splitting technique.

Posters

R.D. Bleach (Naval Research Laboratory, Washington, DC) showed extreme ultraviolet (EUV) and soft x-ray spectra of impurities such as Ar, Fe, and Ni created by the TEXT Tokamak at the Univ. of Texas, Austin. The data were used to determine plasma electron density and temperature.

A. Carillon (Univ. of Paris-Sud, Orsay, France) showed examples of bremsstrahlung radiation that originates in laser-produced plasmas above the critical density region independent of the 1.06- or 0.53-μm wavelength laser used. The observations were explained by temperature gradients in the aluminum plasmas.

J.T. Costello (University College, Dublin) described how laser-produced plasmas could be used as backlighting sources in the 40- to 8,000-angstrom range. For short wavelengths (less than 2,000 angstroms), a high-Z rare earth metal was used. For longer wavelengths, laser sparks formed in high pressure gas were used.

E. Ya Kononov (USSR Academy of Sciences, Moscow) presented results of nonlinear fitting methods to determine wavelengths accurate to 0.03 angstrom for Fe XVIII-Fe XX lines near 100 angstroms produced in laser plasmas.

K.N. Koshelev, also of the USSR Academy of Sciences, gave results of an x-ray spectroscopy experiment involving plasmas produced in a vacuum spark device. A model based on sausage-type instabilities and subsequent plasma expansion was used to explain the observed line broadenings in spectra of targets with Z ranging from 13 to 28.

P. Mandelbaum (Hebrew Univ., Jerusalem, Israel) showed calculations of 3d-4p transitions in Cu-like ions used in conjunction with a collisional

radiative model to determine transitions observed in laser-produced plasmas.

M. Mazzoni (Observatorio Astrofisico di Arcetri, Florence, Italy) measured the relative photoionization cross section of neutral tellurium in the 400- to 1,400-angstrom range more accurately than had been done before; his presentation discussed the results.

Stellar, Interstellar, and Galactic Studies

Invited talks

A.K. Dupree (Center for Astrophysics, Cambridge, MA) discussed some of the high resolution ultraviolet and x-ray spectroscopy satellite-borne experiments that viewed extra-solar sources. The data, like those from laboratory work, are used for plasma modeling.

H. Nussbaumer (Institute of Astronomy, Zurich, Switzerland) showed evidence for broadened emission lines from stars that have large mass loss. He also commented on the need to include dielectronic recombination as an important mechanism in plasmas that have an electron temperature considerably less than the ionization energy.

A. Dalgarno (Center for Astrophysics, Cambridge, MA) presented the effects of discrete x-ray sources on the surrounding interstellar material and discussed various emission mechanisms--e.g., charge transfer, ionization, and fluorescent emission--that are important in the production of x-rays. Proton collisional processes, possible 15- to 55-eV photons from massive neutrino decay, and emission from interstellar molecules such as H^+ were also described.

Contributed talks

J.R. Lemen (Mullard Space Laboratory, Dorking, Surrey, UK) described the proposed European X-80 x-ray astronomy satellite. It will contain Bragg crystal spectrometers, large area proportional counters, crystal scintillators, and wide-field monitors; it will be used to study emission in the 1- to 200-keV range.

C.I. Coleman (Marconi Space and Defense Systems, Stanmore, UK) submitted in abstract form only a description of the European Magellan satellite experiment, which will observe in the 500- to 1,550-angstrom range. A grating spectrometer with about 80-mA resolution will be used to obtain spectra from objects to magnitude 16.

B.C. Mosignori Fossi (Observatorio Astrofisico di Arcetri, Florence, Italy) presented a model to explain the observed C IV and N IV diffuse emission in the direction of the north galactic pole. A temperature of 2×10^5 °K explains the EUV background and the C IV and N IV line emission.

M.C.E. Huber (Swiss Federal Institute of Technology [ETH], Zurich, Switzerland) gave a talk on the use of the branching ratio technique to determine oscillator strengths in C I transitions for modeling comets. Deviations of multiplet intensity distributions from LS coupling calculations were found.

Posters

K.H. Stephan (Max-Planck Institut, Garching, Germany) showed a position-sensitive proportional counter used for measurements of x-rays in the 1.5- to 68-angstrom range. The device is used to calibrate x-ray telescope mirrors.

C.J. Butler (Armash Observatory, Northern Ireland) presented studies of radio, optical, and UV radiation from BY Dra and RS CVn type binary stars. The results agree in part with a model of large spotted areas on the surfaces of the stars. The model needs an extra source of soft x-ray excitation to account for the BY Dra emission.

Theoretical Studies

Invited Talks

Ian Grant (Univ. of Oxford, UK) described the general-purpose computer programs used to calculate atomic energy

levels and radiative transition probabilities. The programs are available from the Computer Physics Communications Program Library at Queens Univ., Belfast, Northern Ireland. Comparisons of these and other codes for two-, three-, and four-electron systems show agreement with experimental values. A.K. Pradhan (Univ. of Windsor, Canada) presented calculations of cross sections and rate coefficients for K-shell emission in ions of interest in laboratory and astrophysical plasmas. Ratios of He-like lines, which can be used as temperature and density diagnostics, were discussed.

Contributed Talks

M.W.D. Mansfield (University College, Cork, Ireland) showed calculations of Ba III wave functions that overlap, thus explaining the observed spectrum.

E. Meroz (Hebrew Univ., Jerusalem, Israel) gave results of calculations of transition arrays from 3d-4p and 3d-4f transitions in Mo and Pd. Calculations of 4d-4f transitions in Ce, Cs, Ba, and Nd having ionization stages XII to XVI agreed with laser-produced plasma spectra.

N. Spector (Soreq Center, Yavne, Israel) showed calculations of 3d-4d and 3d-4f transitions in indium, which agreed with laser-produced plasma spectra in the 20- to 30-angstrom range.

A. Bar Shalom (Hebrew Univ., Jerusalem, Israel) presented new methods of calculating excitation rate coefficients based on distorted wave approximation techniques for highly ionized atoms of Mo and W.

Posters

Mirza Said-uz-Zafar Chaghtai (Muslim Univ., Aligarh, India) analyzed Nb III-IX spectra using calculations based on the Cowan atomic structure code.

D.M. Cochrane (Rutherford and Appleton Laboratories, Chilton, UK) showed that when several methods of calculation were used, excitation rate coefficients of Li-like ions differed by 10 to 50% with the data.

G. O'Sullivan (National Institute for Higher Education, Dublin) showed calculations of Xe I-Xe XVIII radial wave functions. The contraction of the wave function with increasing charge explains the observed intensities of 4d-4f transitions in the XUV range.